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Spektra CS-18P Seismic Calibration System: Reference Measurement Distortion Reduction Efforts

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Introduction

The Facility for Acceptance, Calibration and Testing (FACT) at Sandia National Laboratories hosts a number of capabilities focused on component evaluation, including a Spektra CS-18P seismic calibration system. The system utilizes a laser vibrometer as a means of independently measuring the shake table's motion. We have observed in seismic sensor calibration, and vibration susceptibility tests of infrasound sensors, distortion of the reference laser measurement increases as excitation frequency decreases at and below approximately 1 Hz. Our Spektra system is housed within an active multi-use lab/work area also housing an infrasound source and isolation chamber, environmental chamber and work bench. We suspected the lab's environment may have negative effects on calibration measurements made with the system, and as a matter of good operating practice we limit work activity and use of the lab during calibration measurements. We hypothesized that circulating air in the lab may be affecting the laser reference. To test our hypothesis, we devised a test plan in which calibrations are run on the Spektra S-13 vertical table with a Geotech GS-13 short-period seismometer. Calibrations were run in four different configurations, ranging from those occurring while the system is completely exposed to air circulation induced by operation of the heating, ventilation and air condition system (HVAC), to calibrations occurring with the HVAC off and the laser isolation platform and vertical table enclosed.

The Spektra CS-18P Seismic Calibration System

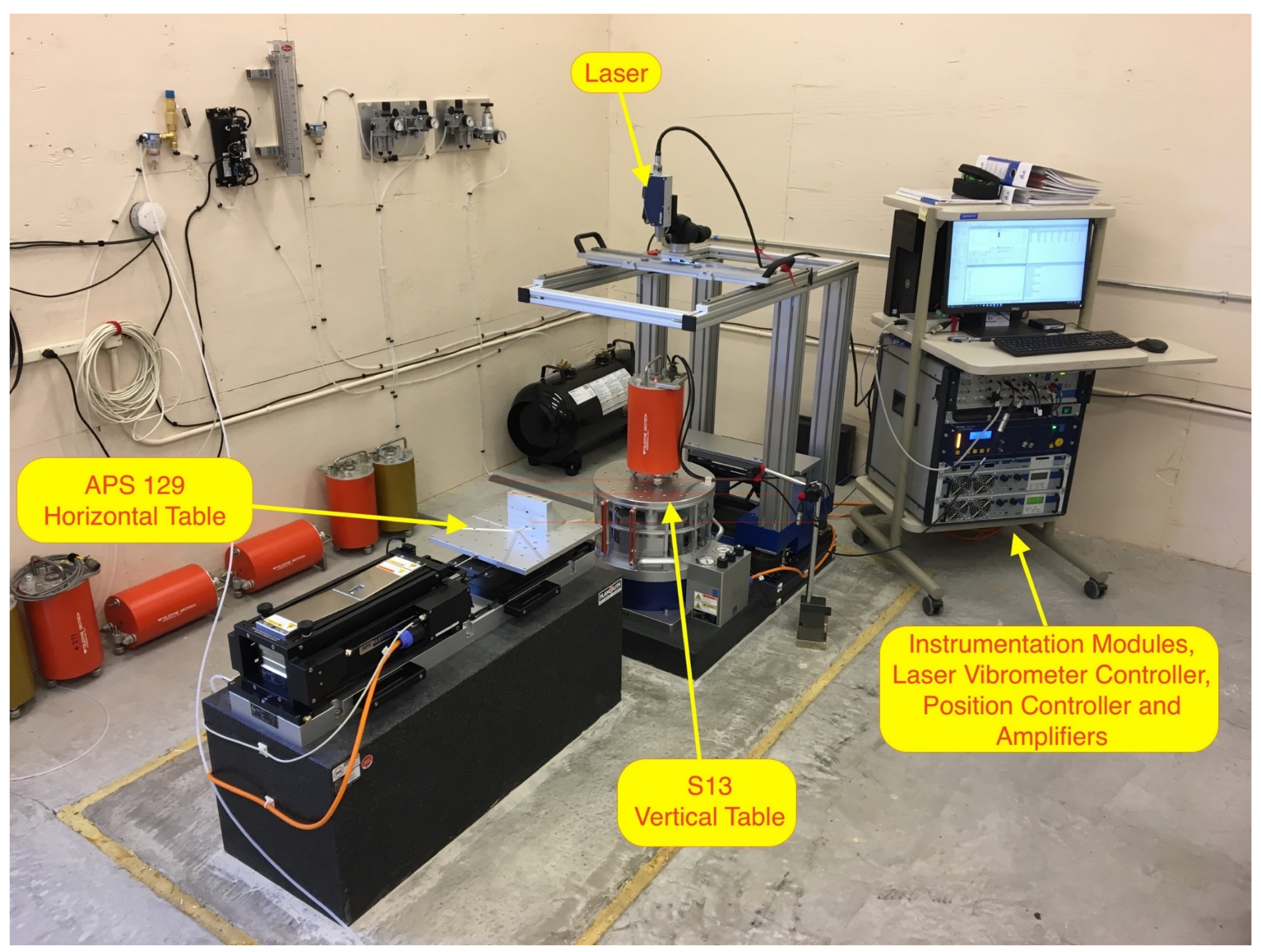


Figure 1. The Spektra CS-18P Seismic Calibration System installed at the FACT site. The system is composed of horizontal and vertical component shake tables, the APS 129 and S13, respectively, a laser vibrometer, with its laser mounted on a vibration isolation platform, a position controller, amplifiers and a computer hosting the operating and analysis software package.

Transfer function

Position number: 1

Frequency, Hz	Vel., m/s Peak	S, mV/(mm/s)	Stdrd. dev., %	Deviation, dB	Phase, Degree	Distor. ref., %	Distor. dut., %
8.000	0.000999	2011.1	0.023	(Ref. value)	-81.177	0.12	0.02
0.100	0.001008	23.951	0.372	-38.482	80.670	1.64	46.95
0.126	0.001016	36.378	0.437	-34.852	78.582	1.85	33.59
0.158	0.001012	55.471	0.289	-31.187	75.709	1.67	24.53
0.200	0.00102	87.376	0.253	-27.241	71.438	1.38	16.78
0.251	0.001014	134.78	0.103	-23.476	66.653	1.16	10.91
0.316	0.001014	209.66	0.035	-19.638	60.420	0.95	7.03
0.398	0.001013	324.1	0.036	-15.855	52.409	0.83	4.47
0.501	0.001012	493.21	0.014	-12.208	42.308	0.68	2.64
0.631	0.001009	728.18	0.016	-8.824	29.620	0.60	1.60
0.794	0.001009	1019.4	0.031	-5.902	14.568	0.51	1.05
1.000	0.001008	1326.2	0.016	-3.616	-2.139	0.42	0.63
1.259	0.001007	1585.9	0.017	-2.063	-18.594	0.33	0.41
1.585	0.001011	1765.9	0.017	-1.129	-33.224	0.35	0.39
1.995	0.001004	1875.3	0.029	-0.607	-45.327	0.21	0.23
2.512	0.001011	1937.8	0.036	-0.322	-55.028	0.26	0.27

Figure 2. Example calibration values taken from a vertical component GS-13 calibration certificate. Note the increased distortion of the reference at lower frequencies (Distor. Ref. %, circled in red).

We have observed in seismic sensor calibration, and vibration susceptibility tests of infrasound sensors, distortion of the laser measurement increases as excitation frequency decreases below approximately 1 Hz. Encircled on the calibration certificate in Figure 2 are the laser distortion values (labeled "Distor. Ref.") for frequencies at and below 1 Hz. Notice the increasing distortion values as the excitation frequency decreases.

Reducing Unwanted Effects on Measurements

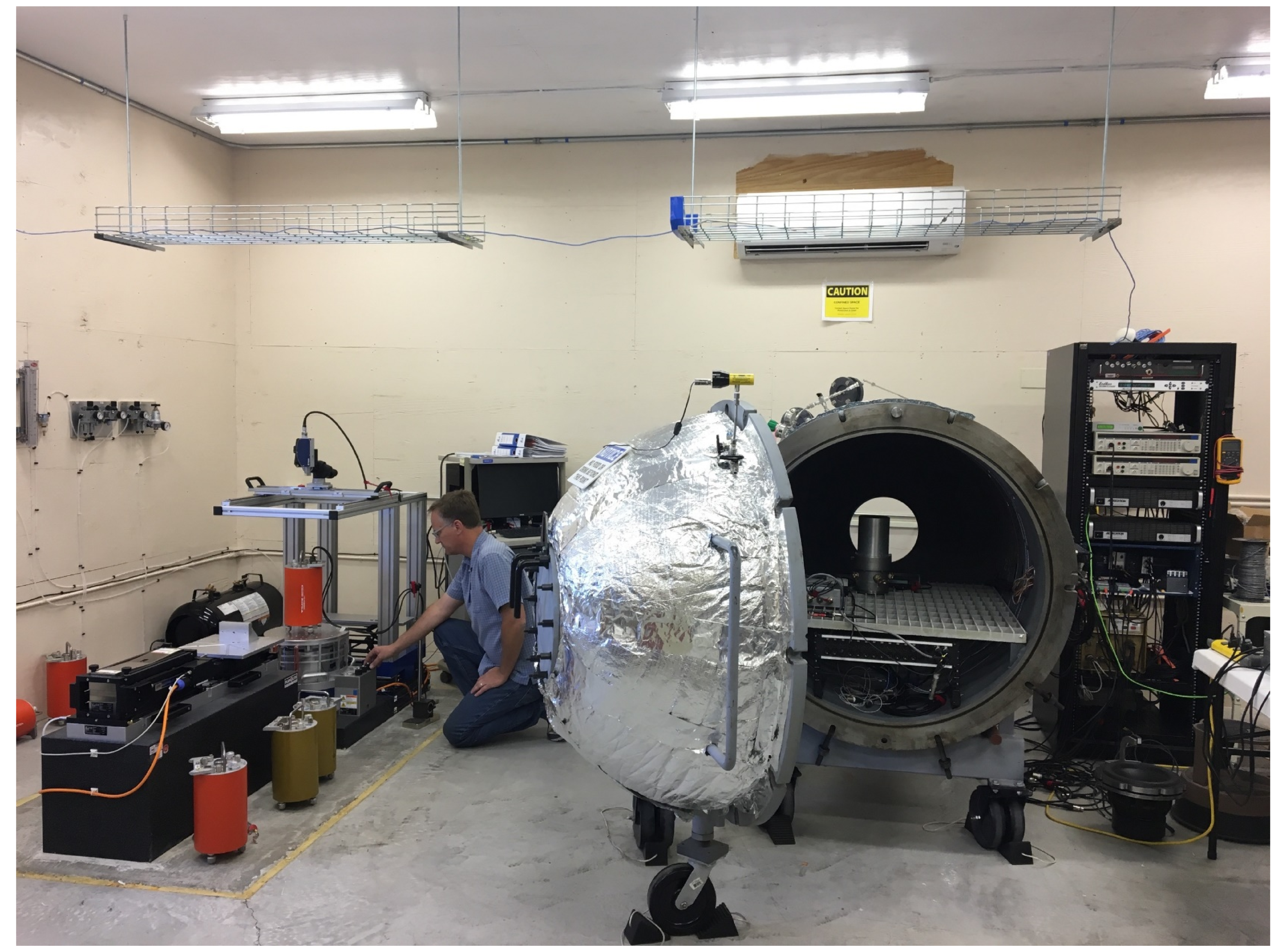


Figure 3. The seismic calibration system resides in a crowded, multi-use facility, hosting our infrasound acoustic isolation and testing chamber (center of photo), an environmental chamber and work/fabrication area.

- Vertical and horizontal tables and laser isolation platform are installed on large granite blocks grouted onto a seismic pier.
- The seismic pier, composed of concrete, approximately 4' wide, 8' long and 3' deep, intended to provide isolation from the concrete pad the building rests upon.
- The heating, ventilation and air conditioning (HVAC) system (Figure 3, top center) is turned off during calibration measurements

Laser Vibrometer Head Unit and Isolation Platform

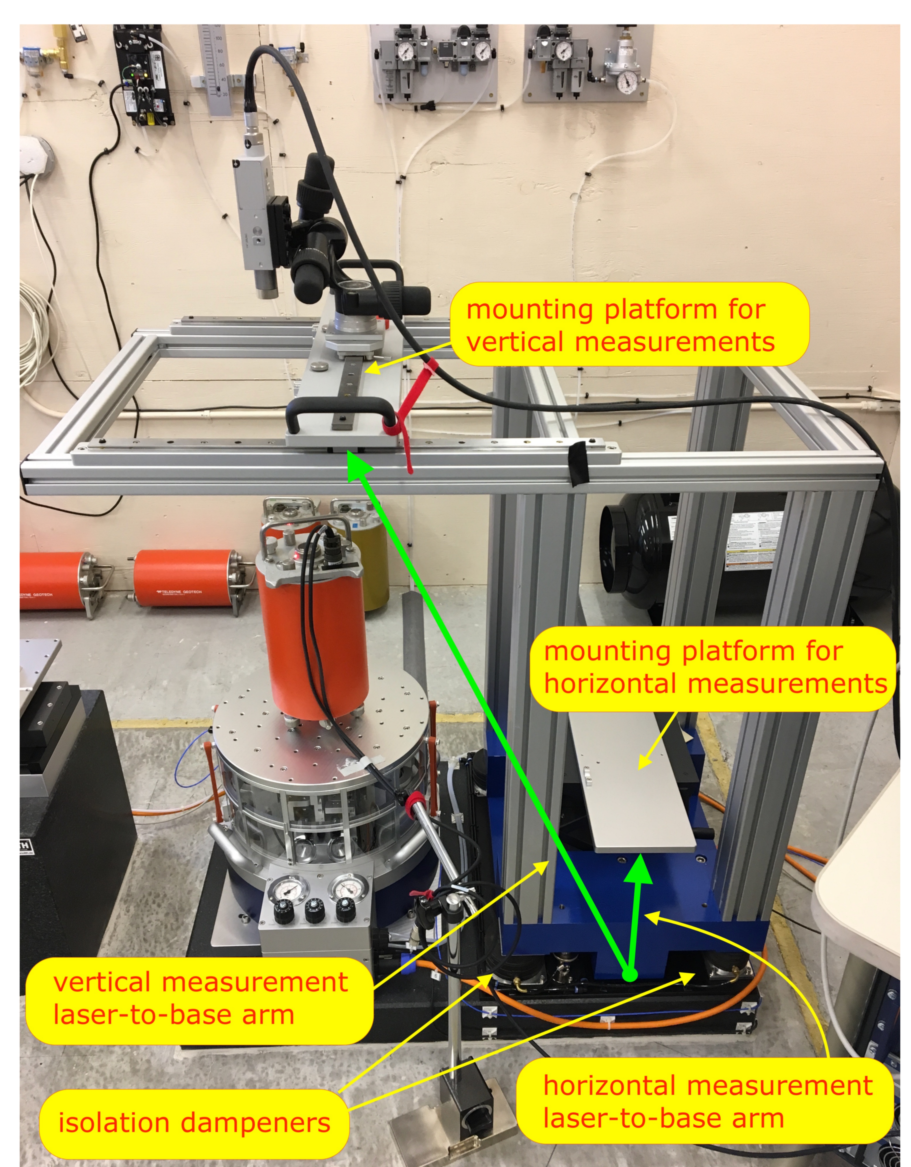


Figure 4. Close up of the S-13 vertical table and the laser isolation platform. Note the relatively long laser-to-base arm with the laser mounted for vertical calibrations.

- Calibration system utilizes an isolation table to support the laser vibrometer head.
- Isolation table's base rests upon compressed air isolation dampeners, intended to provide isolation from vibration coupling to the seismic pier.
- The laser vibrometer head unit may be mounted in a manner to collect vertical measurements of vertical motion on the S-13 table.
- While the system certainly provides isolation from ground-based vibration, it is completely exposed to the ambient air within the room.
- It is feasible the system may offer little isolation from acoustically-coupled vibration or air-currents within the lab, which may induce movement of the laser vibrometer head.

Do Air Currents Affect the Measurements?

An enclosure and curtain were fabricated to attenuate air currents around the laser isolation platform and S-13 vertical table. Ten calibration measurements were taken in four different configurations, while varying the state of the HVAC system and use of the enclosure and curtain.

Air Current Reduction Measures

Figure 5. Air current attenuation enclosure, fabricated from common closed cell foam board utilized as insulation in the construction industry.

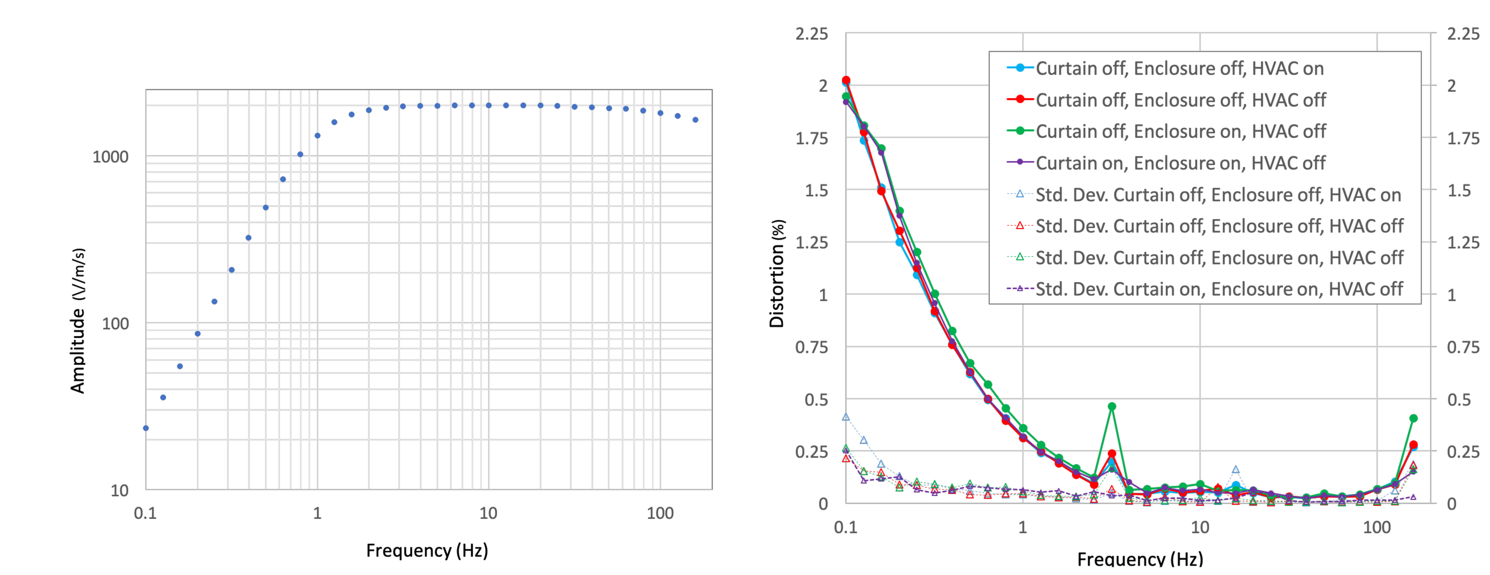
Figures 6 and 7. A small opening in the foam enclosure underneath the laser vibrometer head allows the laser beam to reach the sensor.

Figure 8. Air current attenuation enclosure with a plastic curtain surrounding the S-13 vertical table.

Configurations Tested

Laser Isolation Platform	Vertical Table	HVAC System	Figure
Exposed	Exposed	On	1
Exposed	Exposed	Off	1
Enclosed	Exposed	Off	5
Enclosed	Enclosed	Off	8

Results



Left – Representative GS-13 amplitude response as measured by the calibration system. *Right* – Average percent distortion of the laser reference for each of the four configurations and their standard deviations over the 10 calibration measurement iterations of each configuration.

- Average laser distortion varies only slightly over the four configurations.
- Distortion appears to be highest the while the enclosure is on, HVAC is off and curtain is off, though these differences are well within the respective measurements' standard deviation.
- Average distortion differences between configurations are only significant at specific frequencies: 3.16 Hz and above 125 Hz.
- While distortion is lower at 0.1 Hz in configurations with the enclosure is on and HVAC off, at 0.158 Hz these configurations have higher distortion (the difference greater than the standard deviations of the distortion measurements) than configurations with the enclosure off and curtain off.
- Results of this evaluation were mixed, with no clear improvement in reference laser distortion from the use of the enclosure or curtain shielding the system from the laboratory environment.

Future Work

- Focus efforts on compressor-free operation of system, leveraging compressed air storage tanks during calibrations.
- Attempt calibrations on a broadband sensor (e.g. Trillium Horizon 120).
- Investigate the effects of sensor-under-test anchoring systems during calibrations.

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